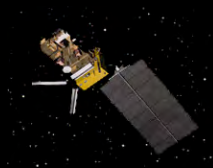
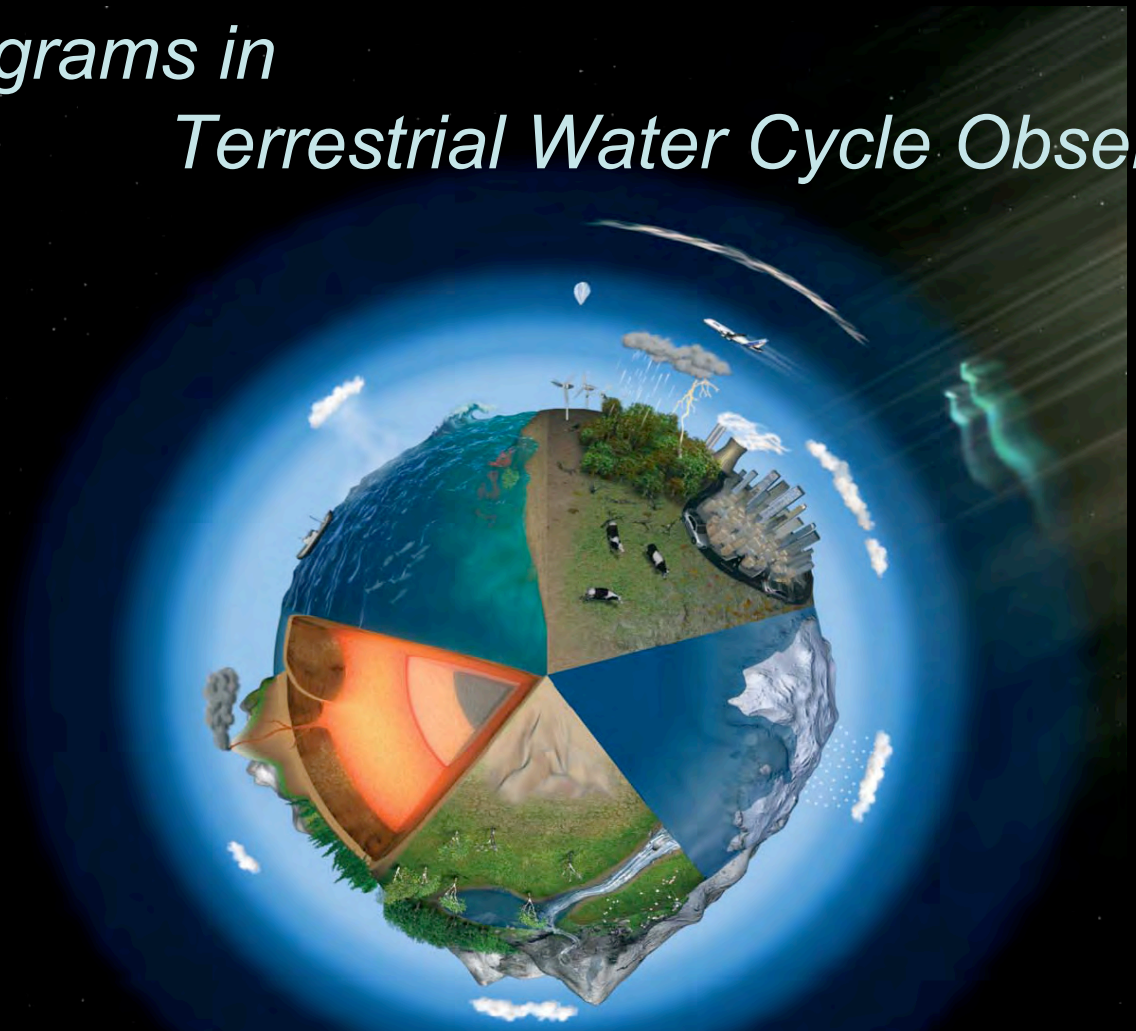
ESA's Programs in Terrestrial Water Cycle Observations





Matthias Drusch and Mark R. Drinkwater

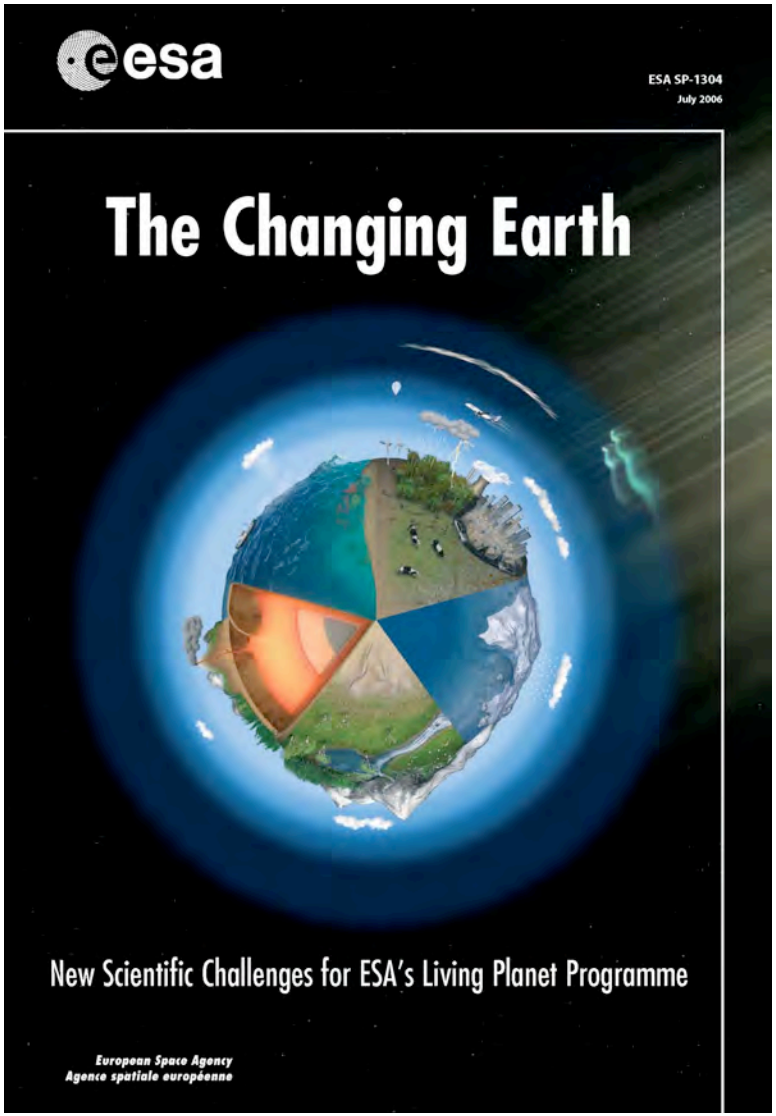
European Space Agency

Earth Observation Programmes

European Space Agency
Agence spatiale européenne

the Living Planet

Scientific challenges for ESA's Living Planet Programme



- Updated Science Strategy for ESA's LPP, after broad user consultation
- SP-1304 identifies key scientific challenges for: hydrosphere, atmosphere, cryosphere, biosphere and geosphere
- Emphasis on the system approach, where interactions and interfaces between different parts of the Earth system are fundamental

ESA's LPP EO Tools

www.esa.int/livingplanet

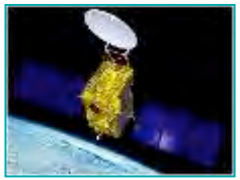
Earth Explorer

Research driven

Core Missions

GOCE
2008

ADM-Aeolus
2009



EarthCARE
2013

Opportunity Missions

CryoSat 2
2009

SMOS
2008

Swarm
2010

? **Earth Explorer 7**
2016

Earth Watch

Operational Service driven

EUMETSAT

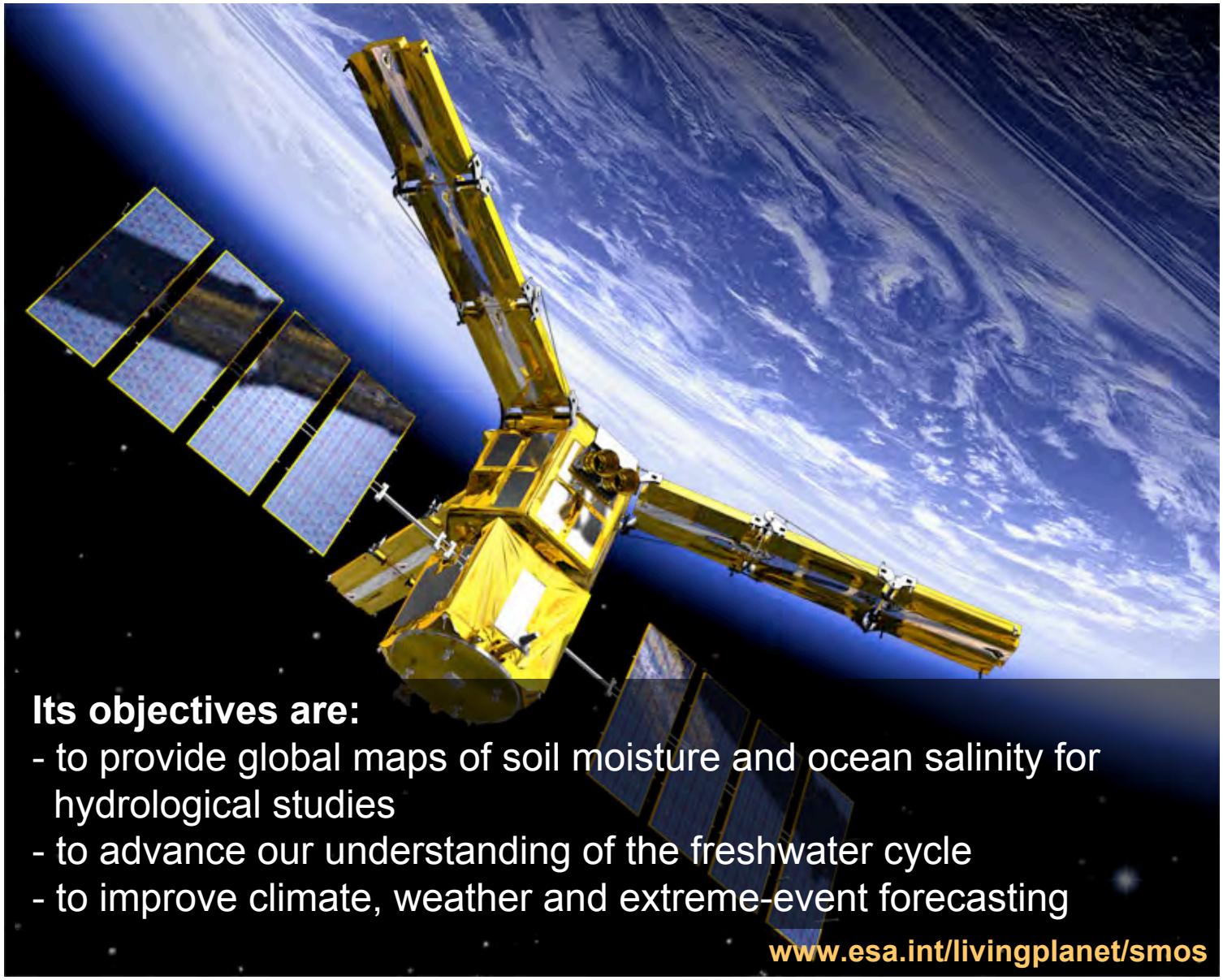
- **Meteosat**
- **MSG**
- **EPS (MetOp)**
- **MTG**
- **Post EPS**

GMES

- **Sentinel 1**
- **Sentinel 2**
- **Sentinel 3**
- **Sentinel 4**
- **Sentinel 5**

+ 6 Candidate Core Explorers

Earth Explorer: SMOS



Its objectives are:

- to provide global maps of soil moisture and ocean salinity for hydrological studies
- to advance our understanding of the freshwater cycle
- to improve climate, weather and extreme-event forecasting

www.esa.int/livingplanet/smos

Earth Explorer Candidate Mission Selection

Step 1: Call and selection

- Call for Ideas — ➢ March - July 2005
- ESAC Recommendation / PB-EO Selection — ➢ May 2006

24

BIOMASS - TRAQ - PREMIER - FLEX - A-SCOPE - CoRe-H_2O

6

Step 2: Mission Assessment (Phase 0)

- Mission Assessment Groups / Phase 0
- 2 parallel industrial studies: EADS Astrium & Thales Alenia Space
- Reports for Assessment — ➢ July - November 2008
- User Consultation Meeting — ➢ 20-21 January 2009
- ESAC Recommendation / PB-EO Selection — ➢ February 2009

Results on www.esa.int

Step 3: Mission Feasibility (Phase A)

- Mission Advisory Groups / Phase A
- Reports for Mission Selection
- User Consultation Meeting
- ESAC Recommendation / PB-EO Selection

➢ 2009 - 2010

≤3

Step 4: Implementation (Phases B, C/D, E1)

- Implementation — ➢ Phase B/C/D: 2011 -2016; ➢ Launch: end 2016

1

The Six Candidate EE7 Missions

BIOMASS
A BIOMASS Monitoring Mission for Carbon Assessment

FLEX
FLuorescence Explorer

Core-H2O
Cold Regions Hydrology High-resolution Observatory

A-SCOPE
Advanced Space Carbon and Climate Observation of Planet Earth

PREMIER
PRocess Exploration through Measurements of Infrared and millimetre-wave Emitted Radiation

TRAQ
TRopospheric composition and Air Quality

http://www.esa.int/esa/LP/LPfuturemis.html

BIOMASS

Primary Objective:

Improved quantification of terrestrial carbon cycle through consistent global forest biomass, forest extent and forest disturbance measurements, augmented by monitoring of wetland areas and forest flooding dynamics.

Secondary Objectives:

Connected with the first opportunity for dedicated P-Band radar measurements from space:

- Mapping subsurface geomorphology in arid zones
- Measure ice thickness (SAR interferometer mode);

Key data:

Global coverage of forests
Forest biomass with 20% accuracy
2 biomass maps / year

Technical concept:

Instrument:	P-Band (435 MHz) Synthetic Aperture Radar
Duration:	5 years
Revisit/obs.time:	≤ 45 days (threshold) with a goal of 25 days
Swath width:	60 - 100 km
Spatial resolution:	50 m × 50 m
Incidence angle:	≥ 25 degrees

CoReH$_2$O

Primary Objective:

To improve the spatially detailed characterisation of snow cover, glacier ice (to be used for glacier mass balance and runoff models) and sea ice with an emphasis on marginal ice zones, ice formation, thin ice, snow burden.

Secondary Objectives:

To improve the representation of snow and ice in land surface models, hydrological models, atmospheric circulation models (initialization, validation, downscaling).

Key data:

Snow extent at 100 – 500 m resolution / 3 – 15 days
Snow water equivalent at 200 – 500 m resolution / 15 days
Sea ice type / snow depth at 200 – 500 m resolution / 3 – 15 days
Glacier, winter snow accumulation at 200 - 500 m resolution / 15 days

Technical concept:

Instrument:	SAR in Ku- (17.2 GHz) and X-Band (9.6 GHz), co and cross pol.
Duration:	5 years
Revisit/obs.time:	two phases of 3 days and 15 days
Swath width:	~100 km
Spatial resolution:	50 m × 50 m

FLEX – The Fluorescence Explorer

Primary Objective:

To quantify the photosynthetic efficiency and gross primary production of terrestrial ecosystems at global scale.

Secondary Objectives:

To contribute to the improvement of the understanding of the role of vegetation in the water cycle.

To globally monitor vegetation stress conditions.

Key data:

Top of vegetation reflectance, fluorescence and temperature.

Photosynthesis rates, chlorophyll content, leaf and canopy biophysical parameters.

Technical concept:

Instruments:

Fluorescence Imaging Spectrometer: O2-A: 750-770 nm, O2-B: 677-697 nm, 0.10 nm spectral sampling

VNIR spectrometer: 450-1000 nm in 5-10nm spectral resolution

SWIR imager: dedicated bands for cirrus detect., dry matter content between 1375 and 1735 nm

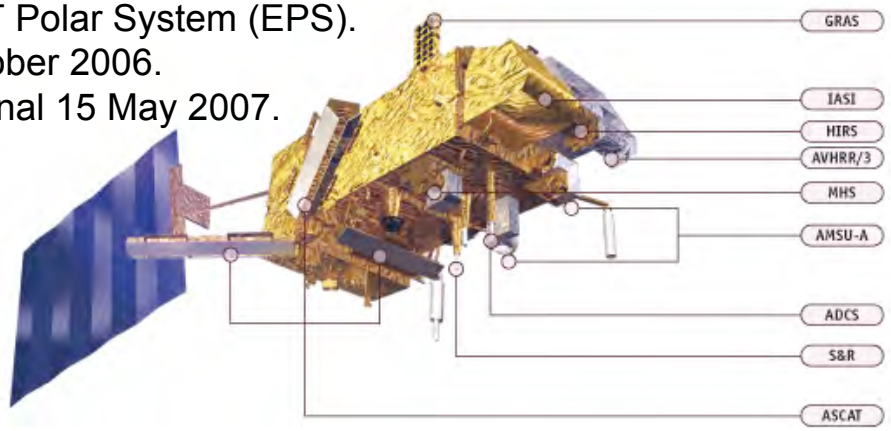
TIR imager: four bands for LST estimates between 8 and 12 μm

Off-nadir imager: 50 deg off-nadir (1km spatial resolution) aerosol instrument

Duration:	3 years
Revisit time:	7 days
Spatial resolution:	300 m

Earth Watch: EUMETSAT METOP / ASCAT

- Metop-A is the first of three satellites of the EUMETSAT Polar System (EPS).
- Launched 19 October 2006.
- Declared operational 15 May 2007.
- www.eumetsat.int

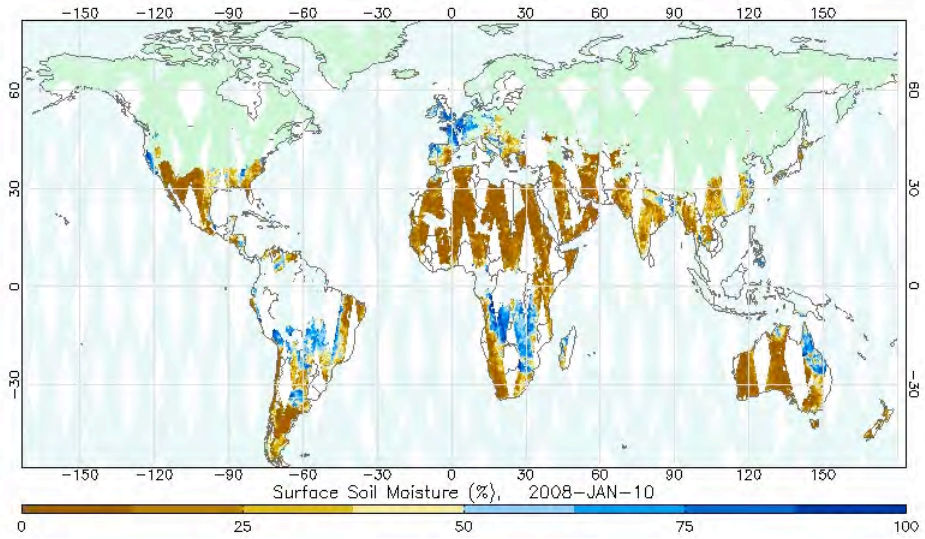


GNSS Receiver for Atmospheric Sounding

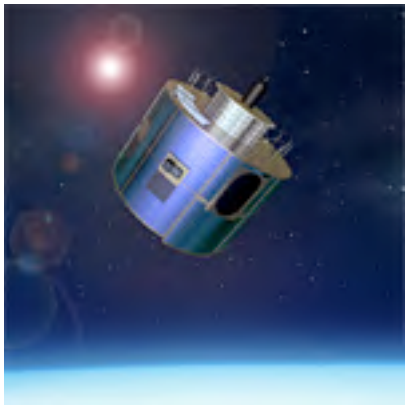
Infrared Atmospheric Sounding Interferometer
High Resolution Infrared Radiation Sounder
Advanced Very High Resolution Radiometer
Microwave Humidity Sounder
Advanced Microwave Sounding Unit

Advanced Scatterometer

- ASCAT is a real aperture radar
- 5.255 GHz (C-band)
- two 500 km wide swaths
- soil moisture indices from Vienna University (W. Wagner) available through EUMETSAT / VU in NRT



Earth Watch:
EUMETSAT Meteosat Second Generation



- MSG is a series of four satellites operating until 2018.
- MSG-1 launched in 2002, MSG-2 in 2005.
- Payload: - Spinning Enhanced Visible and InfraRed Imager (SEVIRI) with 12 spectral bands at 3 km / 15 min resolution
  - Geostationary Earth Radiation Budget (GERB) instruments.

Operational data exploitation for Hydrology through the Land Surface Analysis – Satellite Application Facility (LSA-SAF)

Operational products: - Land Surface Temperature
- Down-welling Surface Shortwave Radiation
- Down-welling Surface Long-wave Radiation

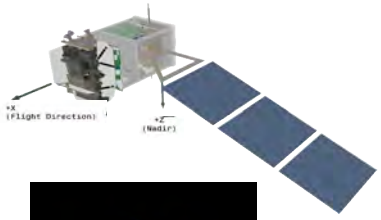
Pre-operational: - Surface Albedo
- Snow Cover
- Evapotranspiration
- Fraction of Vegetation Cover
- Leaf Area Index
- Fraction of PAR

http://landsaf.meteo.pt

EarthWatch:
Global Monitoring for Environment and Security

Sentinel 1 – SAR imaging

All weather, day/night applications, interferometry

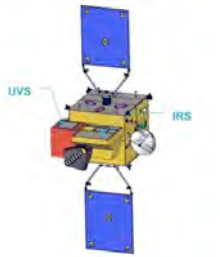


Sentinel 2 – Multispectral imaging

Land applications: urban, forest, agriculture, etc Continuity of Landsat, SPOT data

Sentinel 3 – Ocean and global land monitoring

Wide-swath ocean color, vegetation, sea/land surface temperature, altimetry



Sentinel 4 – Geostationary atmospheric

Atmospheric composition monitoring, trans-boundary pollution

Sentinel 5 – Low-orbit atmospheric

Atmospheric composition monitoring


2011


2012

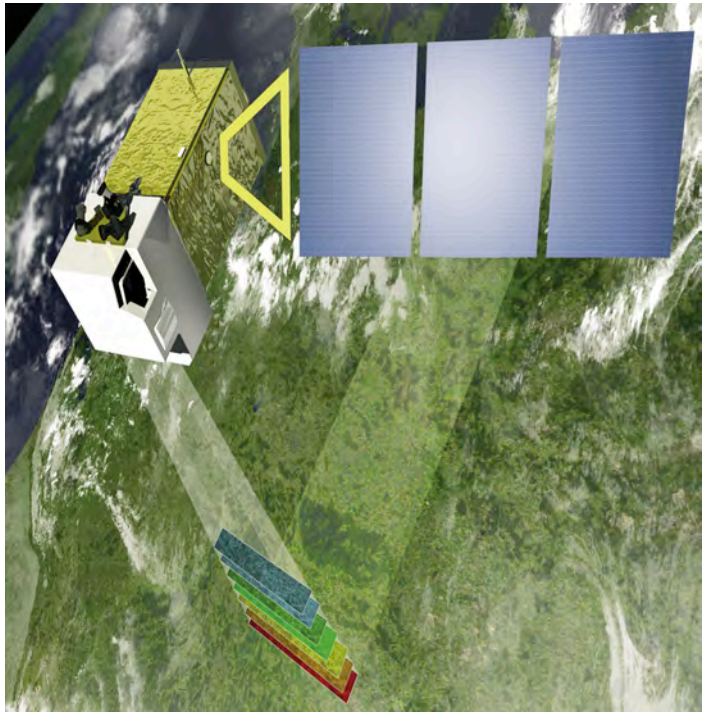

2012


2017+


2019+

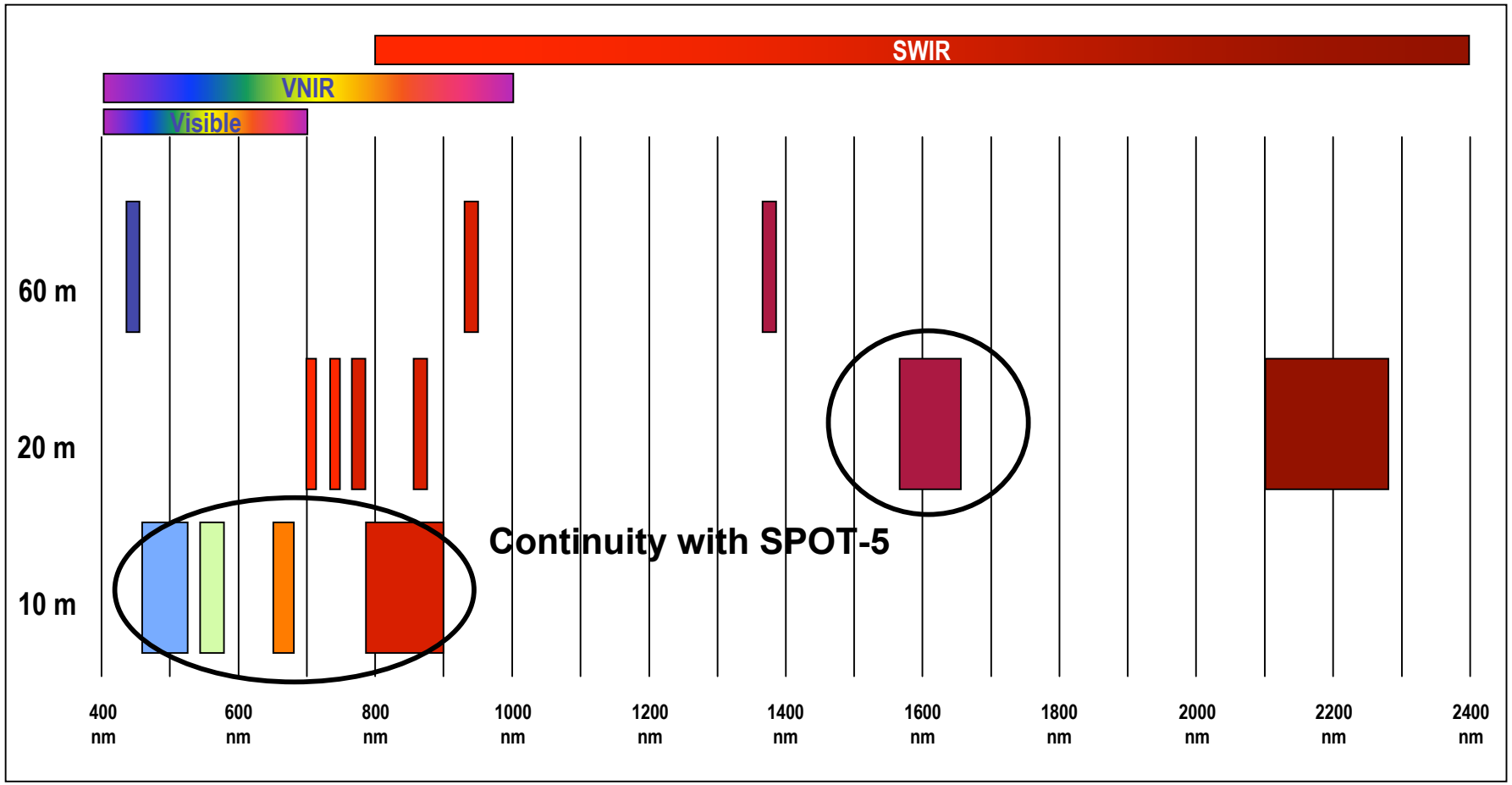
Sentinel - 2

Super-spectral imaging mission



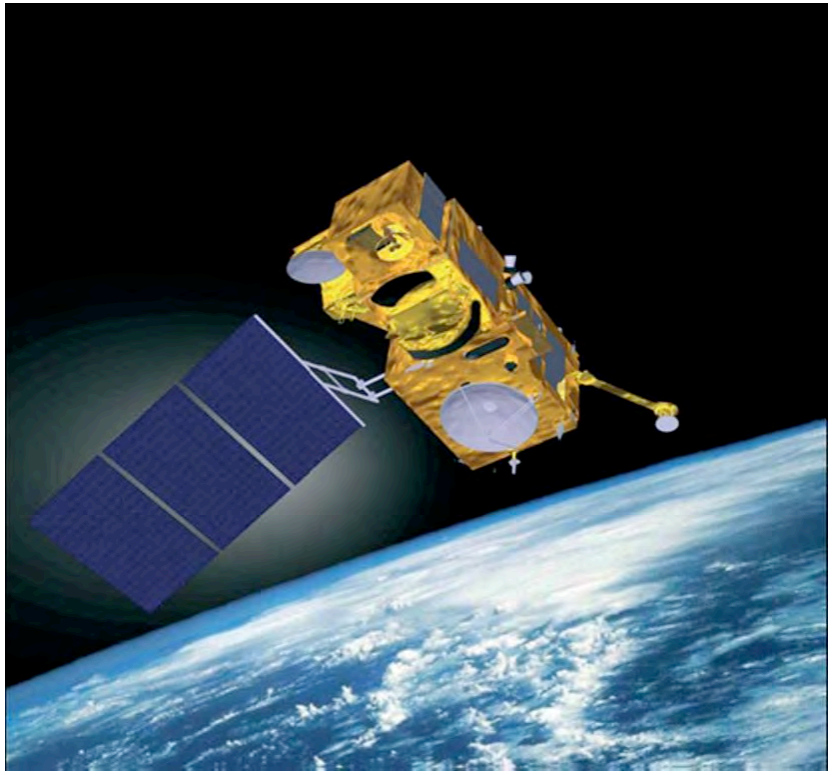
Applications: • Generic land cover maps • risk mapping and fast images for disaster relief • generation of leaf coverage, leaf chlorophyll content and leaf water content
Pushbroom filter based multi spectral imager with 13 spectral bands (VNIR & SWIR)
Spatial resolution: 10, 20 and 60 m
Field of view: 290 km
1098 kg spacecraft mass
10 days repeat cycle
Sun synchronous orbit at 786 km mean altitude
7 years design life time, consumables for 12 years

Sentinel - 2



13 spectral bands versus spatial sampling distance

Ocean & global land mission



Applications:

- Sea/land colour data and surface temperature
- sea surface and land ice topography
- coastal zones, inland water and sea ice topography
- vegetation products

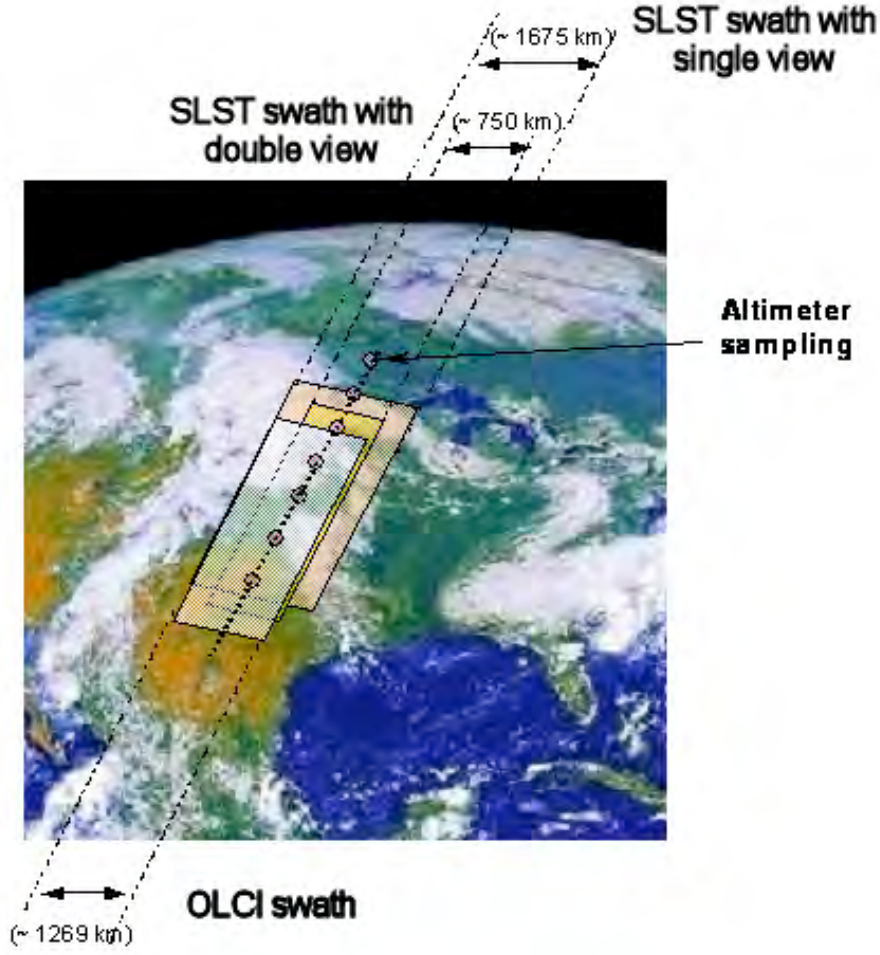
1198 kg spacecraft mass

Sun synchronous orbit at 814.5 km mean altitude over geoid

27 days repeat cycle

7 years design life time, consumables for 12 years

Sentinel – 3 Payload



Topography Mission

- Ku-/C-band Synthetic Aperture Radar Altimeter (SRAL)
- MicroWave Radiometer (Bi-frequency)
- Precise Orbit Determination (POD) including
  - GNSS Receiver
  - DORIS
  - Laser Retro-Reflector

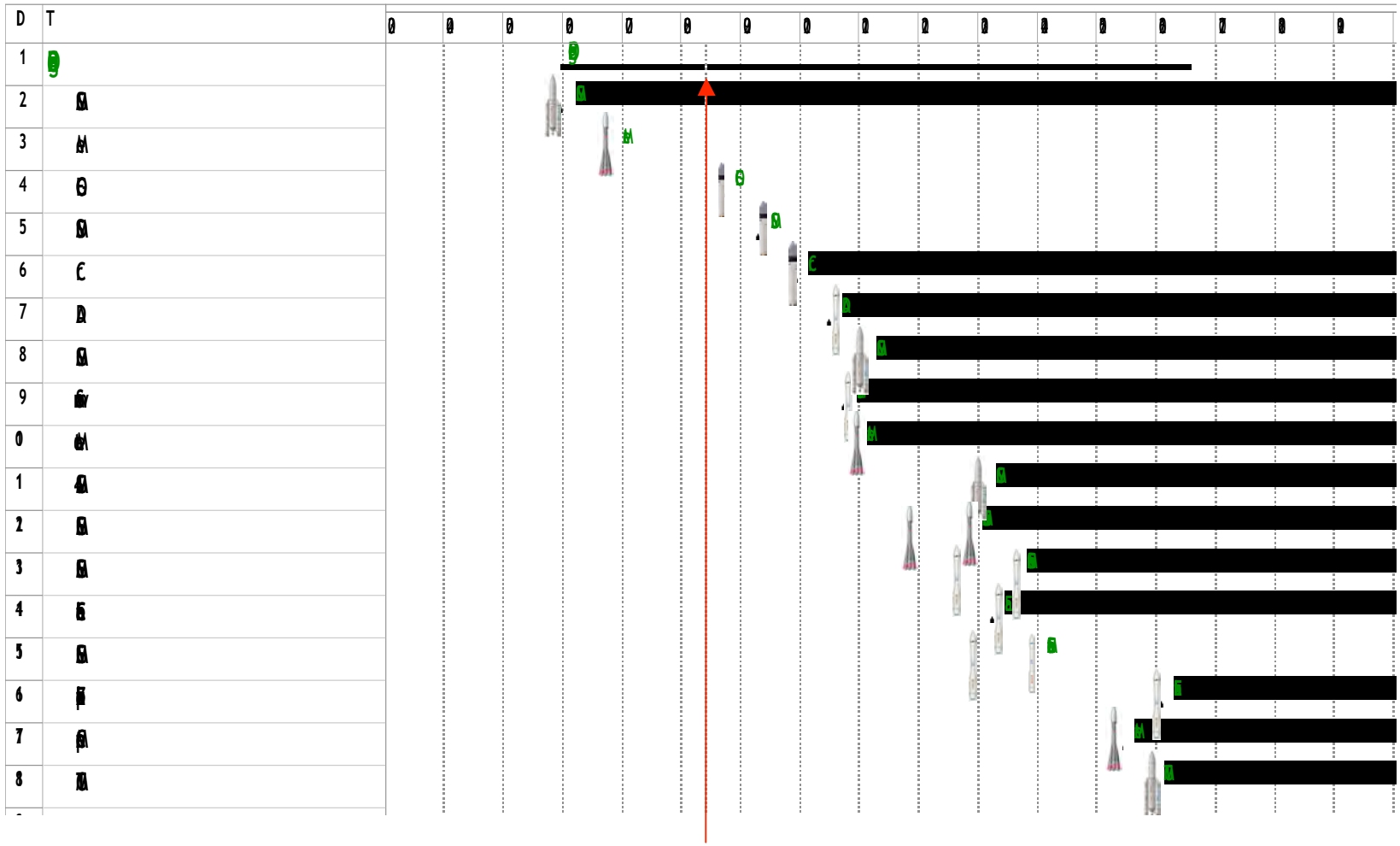
Optical Mission

- Ocean and Land Color Instrument (OLCI)
- Sea and Land Surface Temperature (SLST) Radiometer

Sentinel – 3 / SRAL Altimeter

- Dual frequency Ku & C-band radar altimeter, with technology inherited from Poseidon-3 (Jason-2) and SIRAL (CryoSat)
- Two measurement modes:
  - LRM, conventional pulse-limited mode
  - SAR mode, for enhanced along-track resolution (300 m)
- Two tracking concepts:
  - Conventional closed-loop
  - Open-loop tracking, designed for topographic surfaces (i.e. ice margins, coastal areas)
    - Driven by a DEM stored on-board and by real-time navigation bulletins available from the platform (GNSS & DORIS)

ESA EO Launch Schedule



Conclusions

- The Living Planet Programme features exciting new missions focusing on specific scientific or operational goals
- Six science-driven Earth Explorers are approved and under development (7th EE under consideration)
- 3 operational GMES Sentinel missions (1A, 2A, 3A) approved and under development
  - Sentinel-4/-5 presently under consideration
- ESA to launch a succession of EO satellite missions over the next decade – with which to address key elements of the Earth system

Discussion Point: Near Real Time

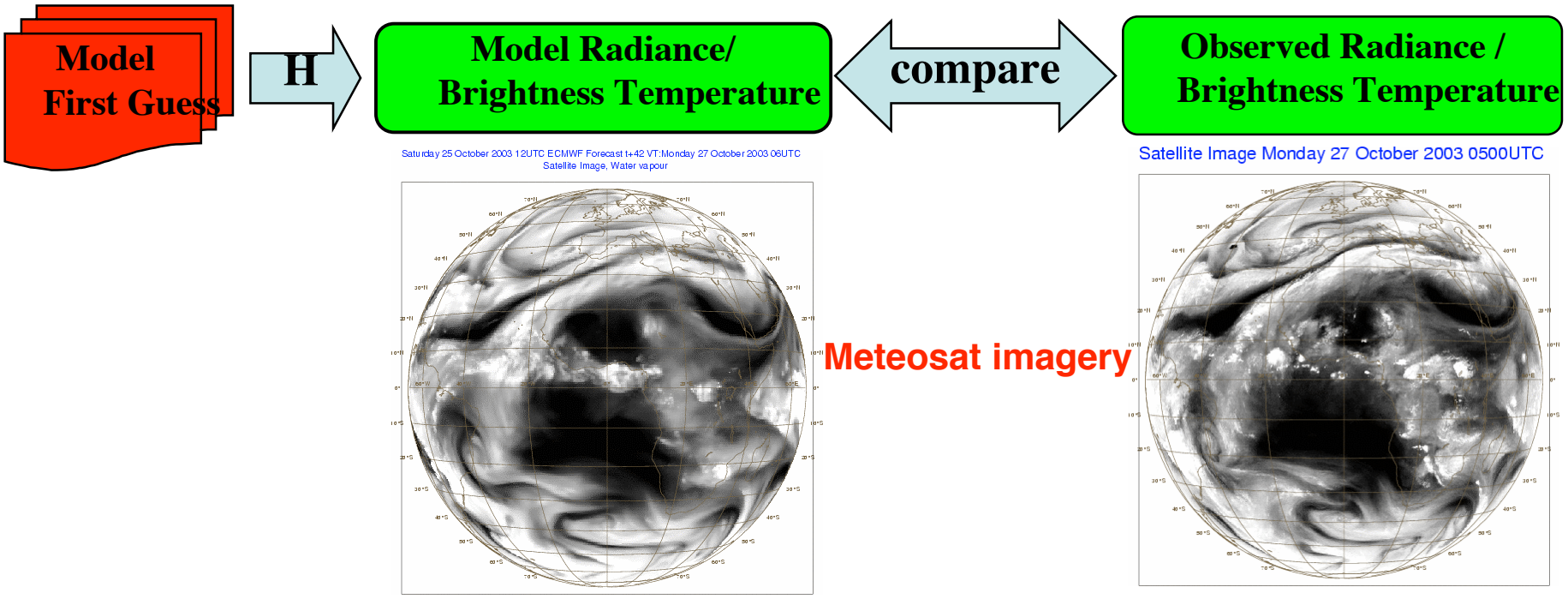
- Near Real Time (NRT) data availability (i.e. within 3 hours of sensing) should be mandatory for every mission!

- There is a trade off between accuracy and latency because of
  a) availability / quality of the auxiliary data
  b) complexity of the algorithm / Level 2 processor (computational costs).

- It may be necessary to design and establish 3 processing chains:
  a) NRT chain up to Level 1C (geo-located and calibrated reflectances, brightness temperatures, …). Do we need NRT Level 2 (geophysical parameters)?
  b) Fast processing chain up to Level 2 (within 2 -3 days).
  c) Re-analysis processing chain for optimized and synergy products (Level 2 and higher; within months to years).

- a) and b) should be provided by Space Agencies.

Discussion Point: Monitoring



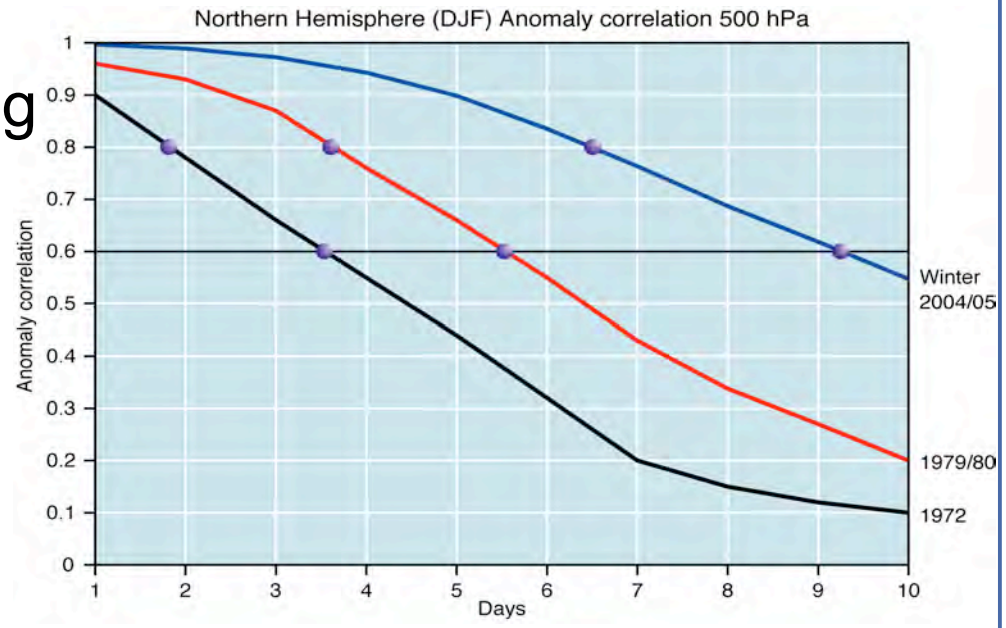
Continuous comparison is mandatory prior to data assimilation!

- To quantify systematic differences for the bias correction.
- To quality check the observations with respect to the model.
- To detect errors, e.g. spikes, drifts and jumps, and to provide timely feedback to the space agencies.

Discussion Point: Quantification of the Impact

NWP / satellite application:

- Observation pre-processing
- Monitoring
- Quality control
- Data assimilation
- Forecast
- Forecast verification
- Impact quantification



Hydrology:

- Standard product validation will be done by Space Agencies (Cal/Val programmes).
- Are additional validation efforts needed?
- Which are the key verification parameters?
- Who will quantify the impact?